



## 2. Financing Innovation: Markets and the Structure of Risk

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### 1. Introduction

As the electro-mechanical industrial revolution unfolded in the early twentieth century, bringing with it the wonders of mass electrification, automobiles, telecommunications and air travel, Australia's business and political elite made sure that Australians could participate not only as consumers, but also as producers. Education and investment combined to guarantee that Australians could understand, develop and employ these technologies. In turn, mastery of these fields underpinned Australia's prosperity, and ensured that the nation continued to develop as a technologically sophisticated society, able to defend itself and provide challenging and satisfying work for its citizens.

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In recent decades, however, as two successive technological and industrial revolutions have transformed the global economy, Australia has failed to build significant positions in either. In software and electronics, Australia has been left behind; in biotechnology it threatens to be. In all three, Australia now participates almost exclusively as a consumer and not as a producer. This weakness shows no signs of turning around, in spite of more than a decade of unprecedented prosperity. Nor has the contemporary Australian economy proven particularly successful at generating new approaches within its traditional industries. Why? This failure to innovate is all the more puzzling since it stands in sharp contrast to the nation's success in established industries over the same period. Why the difference? Why should Australia be apparently so good at 'routine' economic activity and yet so poor at innovation?

This chapter will argue that much of the explanation stems from Australia's failure to develop financial and organisational vehicles capable of managing the special forms of risk inherent in contemporary technological innovation. Australia's effort to build a 'market-oriented' innovation system, the very source of its success in routine economics, may be precisely the factor retarding the nation's innovation performance.

No successful innovating country today relies on free markets alone to finance innovation. There are good reasons for this. While markets are undoubtedly powerful and effective resource allocators, better than any known alternative for most transactions, they fail in the face of certain types of economic challenge because they can't manage the form of information involved – in the case of innovation, they can't manage information asymmetry, moral hazard and adverse selection (these terms will be explained below). As a result of these weaknesses, markets alone neither enable innovators to capture sufficient returns, nor to insure adequately against the consequences of failure.

An effective national innovation system must therefore comprise both market and non-market resource-allocation systems, for different economic and technical tasks. And all effective systems do. But Australia has recently tended not to. An unsought consequence of over-reliance on the very factors that make Australia so good at routine economic activity may actually retard its ability to cope with the particular challenges inherent in contemporary innovation.

This need not be so. Nothing intrinsic to Australian society, geography or demographics says it cannot develop world-class technology companies. It is not 'too small', 'too isolated' or 'too conservative'. It is not less entrepreneurial than other developed countries, or less scientifically creative. In aggregate, it has the human and financial resources. To understand what might be done to build upon Australia's free-market system – which this writer wholeheartedly supports and wishes to extend – and to facilitate innovation, it will be useful, first, to provide an overview of the special characteristics of risk in innovation, then to survey the range of economic vehicles available to manage economic risk of different kinds, before finally examining the set of institutions currently employed in Australia. This will provide a platform for discussing initiatives that might improve Australia's innovation performance without sacrificing the fundamental national institutions that have made the core of its economy so strong.

## 2. The Nature of Innovation Risk

Risk is the defining challenge of innovation. By comparison with day-to-day economic activity, innovation risk is present on more fronts and in greater intensity. While risk-taking has always been central to value creation in capitalism – indeed, markets themselves have been described as processes that resolve uncertainty about human needs and the means to satisfy them<sup>1</sup> – innovation poses the issue of risk in more forms, and especially bluntly.

Any economic activity, no matter how routine, necessarily calls forth at least some risk. Neither the actual desires of customers, nor the behaviour of competitors can be predicted precisely in advance of production. Markets help resolve this uncertainty. But attempts to innovate induce a far greater level of risk than is present in routine production. Innovation necessarily implies grappling with the unknown, not only because prices and quantities of given commodities cannot be predicted in advance, but also because the technical qualities and very feasibility of yet-to-be-created products or processes cannot be known or even described with confidence. Markets that don't yet exist cannot be analysed. The parameters of risk-taking in innovation are therefore both more numerous and more severe than those of regular economic activity.

These considerations are vital for understanding the problem economic institutions must confront as they attempt to innovate. If the nature of technical problems shifts, so too must the social and organisational vehicles needed to undertake them. And indeed, the economic and organisational dimensions of innovation have been changed notably over the last century. Contemporary technological innovation is enormously more complex and uncertain than it was a century ago. This has fundamentally altered the character of the organisational task facing innovators.

Complexity can be defined as the number of elements, and element interactions, a technical system requires to deliver its intended functionality; and uncertainty of the degree of perceived inability to predict the future state of these elements accurately, either because of a lack of information or an inability to discriminate between relevant and irrelevant data. Both these parameters have risen substantially over the last century, especially in the technical systems at the centre of innovation. As the functionality of technology has grown, so too has the number of components in the technical systems required to deliver that functionality. In turn, as the

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number of system elements has increased, so too has the range and depth of technological knowledge needed to master these systems, and individuals have been forced to become increasingly specialised. Any individual can now master only a smaller and smaller proportion of the total. Finally, because all the elements must be integrated to form a coherent whole, the number of elements in the *organisational* systems required to undertake innovation has expanded, sometimes exponentially. A few examples will suffice to illustrate:

- components in a typical automobile: 1920 – 1500; 2003 – 30 000
- components in an aircraft: 1945 – 20 000; 2003 – 3 500 000
- components in a handgun: 51 (musket); 140 (rifle)
- transistors on a typical chip: 1970 – 1000; 1980 – 100 000; 2003 – 100 000 000.
- lines of code in a software operating system: 1980 – 10 000; 2003 – 80 000 000.
- Interconnects in a Private Branch Exchange (PBX), telephone switching system: 1950 – 1000; 1990 – 100 000 000.

The size and intensity of risk inherent in any innovation project depends on the structure of the technology itself. Innovation risk can be measured along three dimensions: scale, duration and intensity.

The phenomenon is general; the world really is getting more complex. This rise in technological complexity and uncertainty, and accordingly in the complexity of the social systems required to develop technology, has heightened the inherent risk of innovation. The parameters of risk are multiplied by complexity and intensified by uncertainty. Complexity magnifies both the real difficulty of uncertainty management, and its perceived difficulty. By multiplying the number of variables in which unpredictable variation is possible, additional complexity increases the possibility of technical failure. But, in addition, by multiplying the number of variables of which human managers must take account, complexity increases the social and cognitive challenge of innovation, and hence its human-derived risk.

Thus the size and intensity of risk inherent in any innovation project depends in the first instance on the structure of the technology itself. Innovation risk can be measured along three dimensions: scale, duration and intensity. Scale refers to the minimum necessary investment needed to bring an individual innovation to market. *Duration* refers to the minimum period required before an outcome is known. *Intensity* refers to the likelihood that the product will make it to market. The greater the first two factors, and less the third, the greater the project's overall risk.

The innovation scale of a technology depends upon the minimum resource commitment that must be made to an individual project within it. This is sometimes referred to as it 'lumpiness'. Lumpiness will be determined by the minimum efficient scale of the proposed technology, and, again, by its complexity. Complexity is also a factor in determining the minimum duration required to complete an innovation project. The more variables that must be tested, and the more variable interactions that might be important to the technology's functioning, the longer the time needed to determine its feasibility. Also important in determining time-commitment is the number of environmental variables with which the technology must interact, and their criticality.<sup>2</sup> A new drug, for example, might not only itself be molecularly complex, but will also be the product of a complex production system. It will then interact with an even more complex system – the human body – and be subject to severe demands of criticality, such as

an exceedingly low rate of side-effects. A company attempting to bring it to market will also be required to test the molecule, and to document that it has been tested, under a wide range of potential failure modes. Under such circumstances, the period required to perform all these tests may extend to many years; in the case of drug development, to more than 10 years. Because science is pushing ever faster against its frontiers, and business has moved closer to those frontiers, the uncertainty inherent in contemporary innovation has escalated.

Risk intensity, or (inversely) success probability, is influenced by the maturity of the science base upon which a new technology relies. Where the science and the engineering knowledge associated with the technology is mature, the character of physical elements will be well established, as will the systemic interactions of those elements. Most electronic projects, for example, rely upon a well-characterised base of solid-state physics and materials science, and the probability of their technical feasibility can be predicted with some accuracy. Projects that rely on the much-less mature biological science base are inherently less certain, and any individual project is less likely ultimately to succeed.

But success probability for most innovation projects depends on more than just technical feasibility. Just as important, and often more important, are two other dimensions of risk: market size and managerial capability. Will the product appeal to consumers, and to how many? Does the management team and organisation attempting to devise and perform all the tests required to bring the product to market possess the required capability? These considerations are often just as important as whether the device actually works.

The intensity and location of risk thus varies by industry and technology. In some sectors, the technology itself is likely to be feasible – to function as anticipated – but identifying a market sufficiently large to justify the investment required to introduce the technology may be problematic. Many innovation projects in information technology will be of this type. In other technology types, a market will probably be available, but whether the technology will operate as anticipated, or can feasibly be scaled from laboratory bench top to production facility, will be more uncertain. Drug development, and especially biotechnological projects, are often of this type.

In general, innovations closest to the scientific and technological frontier will pose the most extreme risk: the lowest probability of success, the largest minimum resource commitment, and the longest time frames to bring them to fruition. These considerations help us understand the appropriate risk management vehicle for each risk type. Not all vehicles are appropriate for all types of risk.

### 3. How Innovation Risk is Managed

To induce individuals and firms to attempt to create new technologies in the face of such risks, two factors must be present. First, profits substantially greater than those to be won from 'normal' economic activity must be on offer. Second, potential innovators must also be assured at least some degree of protection from the consequences of failure. The bigger the innovation – that is, the greater the complexity and the more the uncertainty that must be overcome relative to the innovator's resources – the greater is the need for such super profits and protection from catastrophe.

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Successful innovation offers some above-normal profits more or less 'naturally'. Being first to market with a new product that buyers want provides an opportunity for (at least temporary) monopoly pricing power. Such super profits will not always, however, provide sufficient incentive to confront the risk to innovate. An efficiently functioning market, with technically capable firms, will soon allocate resources to compete away such profits. Indeed, the more efficient the market, the less incentive firms face to innovate. One of the simple ways governments encourage innovation is by blocking the natural action of the market to compete away such super profits, by extending this period of monopoly through the creation of intellectual property rights, such as through copyright and patents. Without such market-blocking, the drug industry, for example, would swiftly implode.

Protection from the downside, however, does not come naturally. Downside risk must be managed deliberately, by organisational vehicles designed specifically for this purpose. Such vehicles can employ one or more of only three potential tools. They can attempt to *reduce* risk (by, for example, changing behaviour); they can *hedge* it (shift it from the principal innovators to a different group more able or willing to bear it); or they can *diversify* it (spread it across a wider base). The latter two can be seen as forms of risk reallocation.

Risk reduction is always difficult in innovation, and usually impossible. For other types of risk, such as personal injury, the government can prevent exposure. It can, for example, outlaw dangerous activity. The risk of driving a car can be reduced by mandating speed limits, imposing quality controls on automobiles, and even forbidding distractions such as the use of mobile phones while driving. But such measures are rarely feasible when risk derives from innovation. The risk in innovation, particularly technical risk, is frequently irreducible, at least at the outset. Government can, however, reduce market risk by, for example, guaranteeing to prefer local suppliers over foreign rivals, or granting tax concessions. It can also attempt to reduce managerial risk by supporting management training, or encouraging technically skilled personnel to move from academia.

More commonly, however, institutions must manage innovation risk by hedging or diversification. Hedging attempts to move risk from the originating party, in this case the innovator, to another who is more able or willing to bear it. It is thus a form of risk redistribution. Such movement of the burden of risk is usually accompanied by payment for risk bearing; that is, others are paid to expose themselves to the risk the originator is not willing to bear. A market for risk, or more precisely for the time-, intensity- and lumpiness-adjusted rewards of risk, can thus develop.

Most of those willing to bear such risk, in turn, employ diversification to make the risk from any specific enterprise tolerable. Diversification works on the principle that the *per-party* burden of any given risk declines as more instances are pooled in a portfolio, and then shared among more risk-bearers. Note that the *aggregate* amount of risk in the pool does not change – risk itself has not been reduced, and the same number of innovation projects will fail as before they were pooled – only the impact of any losses suffered on particular individuals is reduced by sharing. By the same token, the per-party opportunity for windfall has been reduced, also by sharing.

The magic of diversification for innovation is that by pooling resources and risks it makes feasible projects of much greater scale, complexity and uncertainty than would be possible for any individual. How many individuals could bear the risk of a space program, for example, even if they could raise the necessary finance? The drawback, however, is that as the complexity and uncertainty inherent in technological projects mounts, so too the scale and breadth of risk-bearing entities must escalate. Such risk-managing bodies then become difficult to manage, and at the extreme, exceedingly so. In contemporary society, and for some aspects of science-based industry, the scale required to assume the risk inherent in some projects has grown from individuals, to partnerships, to organisations, to governments, and even to multi-government or global bodies.

Fortunately, per-party risk declines sharply with each pooled project and incremental risk-bearer, even for the out-sized risks stemming from innovation. A simple example will illustrate the power of large numbers in risk bearing. Consider a hypothetical gold prospector. Searching for gold is risky, with a low success probability, let's say, for the sake of an example, 1 per cent in any given year; but it's profitable if successful, let's say \$100 000 for the average strike. The expected value of such an undertaking is therefore \$1000 (1 per cent probability of \$100 000, plus 99 per cent probability of nothing). While the expected value of this undertaking is positive, few citizens in fact turn to gold prospecting because the risk is too high. A 1 per cent chance of finding gold means it is overwhelmingly likely that in any given year the prospector will not realize even \$1000, and will waste his or her time. Indeed, it is likely he or she will derive no income 99 per cent of the time.

As if by magic, however, a little diversification can substantially improve the odds of gaining at least the \$1000 sum for the individual and more diversification can virtually guarantee it. With two prospectors agreeing to pool their searches and divide their finds equally, three outcomes are possible: (1) neither finds any gold (98 per cent); (2) one finds gold worth \$100 000, the other nothing, giving each \$50 000 (1.98 per cent); (3) both find gold, giving each \$100 000 (0.01 per cent). Note that the expected value remains \$1000 per prospector. With only two risk-poolers, prospecting is still not particularly attractive. With 100 prospectors pooling, however, the odds that one will find gold, bringing the gain of each to at least \$1000, grow to a comfortable 63 per cent; with 1000 prospectors, the odds of at least one finding gold grow to an overwhelming 99.99 per cent (implying the per-pro prospector gain is \$100). The problem, of course, is that it is exceptionally difficult to organise and sustain pooling among 1000 grizzled gold prospectors.

The same logic holds for innovation, and also from the opposite direction: the probability of successfully bringing a particular innovation to market. Diversification increases the aggregate probability of solving a particular problem. Consider a hypothetical city facing an innovation problem: a plague of mice and no effective mousetrap. Let's assume, for the sake of the example, that the probability any single new trap design will succeed is one in 10, the cost of developing a trap design is \$1000, and the reward of success is \$100 000 to the inventor and to the city a mouse-free environment. The individual inventor thus faces a 90 per cent probability of losing the \$1000 investment in developing the trap, and a 10 per cent probability of gaining \$100 000. The inventor's project thus has an expected

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value of \$9100 (10 per cent probability of \$100 000 plus 90 per cent of minus \$1000), and would make sense for the individual to try. But the city would face a 90 per cent probability of not solving its mouse problem, even if it could persuade the inventor to proceed.

Now consider a circumstance in which the city commissions more inventors to try their hand at designing a mouse trap. Under the same assumptions as before (10 per cent success probability per project), the city now has more attractive alternatives. With two inventors working on the problem, it has a 19 per cent chance of someone building an effective trap; with 10 a 65 per cent chance, and with a 100 a 99.99 per cent chance. The problem is, of course, that the market for mousetraps is still only estimated at \$100 000. With 100 projects underway, the city makes no profit, but its mouse problem is solved. Interestingly, halving the number of inventors at work, to 50, reduces the probability of success only to 99.5 per cent;

dropping the number to 30 reduces the probability to 95.8 per cent. Thus, by diversifying even modestly, the city enjoys an overwhelming likelihood of both solving its mouse problem, and of making a profit of doing so.

The fact that risk can be managed in these ways, that some economic actors are better than others at bearing risk, and that profit can be made from managing risk, implies that a market for risk services will develop.

What is the price of this strategy? One trade-off is already apparent in our gold prospector example. Along with the reduction in risk of failure, diversification shrinks the probability of gaining a more desirable outcome than the expected value. Already with only two prospectors, the probability of gaining \$100 000 per prospector had been reduced by 100 times (from 1 per cent to 0.01 per cent). This explains why gamblers, who play for the love of risk-taking, rarely pool their activities. It also goes a long way towards explaining why gold prospectors don't either. For prospectors, the lure of the big pay-off, however remote a likelihood, provides much of the inducement.

The strategy also requires certain preconditions to have been met. The most important is that the risks being pooled are truly independent of each other. If all our prospectors are looking in the same place, or all have been supplied with similarly rusty prospecting pans, then all are affected by the same factor, and the actual risk has not been diversified. The 'pooled' risk under these circumstances is essentially the same as that of the individual. Similarly, if all mouse trap designers were trained in the same school, and therefore all take a similar approach to a mouse plague, the real probability of finding a solution will not be increased by pooling. The need to meet such preconditions points to the difficulties economic institutions face in coping with innovation risk.

#### 4. Markets as Risk Managers for Innovation

The fact that risk can be managed in these ways, that some economic actors are better than others at bearing risk, and that profit can be made from managing risk, implies that a market for risk services will develop. This is as true for innovation as for other forms of risk. Some economic actors can potentially be better risk managers than others for two reasons. The first is that they might be better able to diversify. They may be larger, or have access to a wider range of independent projects than others. Banks and insurance companies, for example, rely on this advantage to enable them to assume risk from individuals. Larger companies can spread the risk across a greater number of bets. Venture capitalists also rely on size to share risk with entrepreneurs. Second, some economic actors may be better than others at choosing projects for inclusion in a risk-management portfolio. Specialist risk managers cultivate expertise and experience at judging and balancing the

multi-sided risk inherent in innovation projects. Venture capitalists are (or should be) much better at assessing the market and managerial risk in new ventures than are individual entrepreneurs themselves.

In addition, however, some may actually be able to reduce the risk in a particular innovation project. How might this be achieved? For a firm with deeper scientific, technical, or managerial capabilities, the risk inherent in a particular project might be substantially lower than for another lacking those capabilities. When a pharmaceutical company buys the rights to a candidate drug from a biotech start-up, for example, it can actually reduce the risk that the product will fail to reach the market by combining its own capabilities with those of the project team or initial sponsoring company. The chance that a start-up biotech company can not only invent a potential new drug, but also successfully manage the complex process of clinical trials, interact effectively with regulatory agencies, scale up manufacturing processes, and distribute the product through a nationwide or global distribution channel, are much less than those of an established pharmaceutical company. By taking over the project, and plugging it into its own development portfolio, the company has effectively reduced the project's risk.

Other reasons why markets develop for innovation risk include differential risk aversion levels, including those due to differential risk *impact* levels, and portfolio balancing. Risk aversion levels vary either simply because some parties are less fearful of risk – a few actually enjoy risk – or because some (for example, the rich) are more capable of withstanding the impact of losses, especially at the margins. Those with greater fear of risk can then attempt to 'sell' the risk to others who are more comfortable with it. In innovation, this might take the form of partnering, outsourcing certain activities, or pre-selling the yet-to-be-realised product to a major customer.

But parties might agree to exchange risks simply in order to re-weight their portfolios, and align time periods. Firms processing raw materials for which year-round capacity utilisation is important, for example, seek to balance the price they pay for inputs, so as not to face price spikes in non-harvest periods. They do this by buying and selling futures contracts from others, including farmers, who may seek to 'lock in' stable prices for their products in advance of harvests.

All these are powerful reasons why different economic actors will seek to trade and exchange risk. And indeed, this desire has generated a wide variety of tools, techniques and vehicles for buying and selling risk: bank loan portfolios, put and call contracts, a dazzling array of derivative contracts, insurance contracts and so on. In turn, the creation and spectacular growth in recent times of these instruments has spawned a wide variety of markets for trading risk. These include the Chicago Board of Trade Futures Exchange, and many markets for options and other derivatives of stocks, loans and currencies.

Some economists have been led by this proliferation of instruments and exchanges to hope that all risk, including risk in innovation, can be managed through market exchange. It is a laudable hope, since indeed if all risk could be managed through markets, the organisational and managerial overhead would be much lower, and the results would be more available to entrepreneurs. Life for innovators would be much simpler. The only role for other institutions, and policymakers, would be to support markets, and to help them be as liquid, transparent and flexible as possible.

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Several factors combine to inhibit the growth of markets for risk. Two widely observed defects in the information surrounding risk available to market participants — adverse selection and moral hazard — undermine the action of markets.

But in order that markets for risk come into being, several conditions must be met. Of central importance are conditions relating to the availability of information. In essence, the same information must be accessible to all actors. If this condition is breached, buyers and sellers cannot reliably estimate the degree of risk inherent in any position, and cannot establish a real value for the risk management instrument. Similarly, for markets to establish a price for the instruments, these instruments must be made sufficiently similar in key respects that they can be compared effectively.

Unfortunately, in markets for risk, and as we will see, especially markets for innovation risk, such conditions are frequently *not* met, and cannot be met. Several factors combine to inhibit the growth of markets for risk, particularly of certain types and under certain conditions. Two widely observed defects in the information surrounding risk available to market participants undermine the action of markets. These are commonly termed *adverse selection* and *moral hazard*. Both are virulently present around innovation, and lead to severe information asymmetries in the markets for knowledge and technology risk.

Adverse selection occurs when the sellers of risk know more about the degree of jeopardy involved in a particular transaction than do buyers. The result may be that the most risky projects are sold too cheaply; the worst risks 'select themselves' for inclusion in the sale portfolio (hence, the term 'adverse selection,' from the point of view of the risk buyer) — this is to the disadvantage of risk managers. Sellers keep the best, least risky, projects to themselves. Frequently, adverse selection results in risk managers discovering that rather than managing an unbiased portfolio of independent risks, which is, as we have noted, a necessary condition for enabling diversification to function effectively, they have accumulated a group biased towards the most risky. When buyers fear adverse selection, they retreat, and the market for the type of risk subject to this defect crumbles.

Whether a problem of this type might exist in markets for knowledge was tested by Harvard Professor Gary Pisano in the arena of biotechnology.<sup>3</sup> Pisano found it did exist. He took a 1970 article by Berkeley economist George Akerlof,<sup>4</sup> in which Akerlof framed what has become known as the 'lemons' problem, and used data from R&D alliances in biotechnology to test for evidence of the problem Akerlof postulated. Akerlof's argument was that in transactions in which the parties could access differing levels of information — that is, in which information was 'asymmetric' (Akerlof's example was used cars) — buyers could not tell the difference between a good product and a defective one. Only the seller of a used car, and not the buyer, really knows whether the shine of the hood conceals unrevealed defects. In this circumstance, Akerlof argued, even if the car was in fact good, buyers would discount *all* cars in the used market, compensating for the risk that the particular one they were buying concealed unsuspected defects.

The size of the discount would be derived from the expected probability that the particular car the buyer gets will be a 'lemon'. If the expected probability of unwittingly purchasing a lemon is 50 per cent, the buyer will discount the purchase price by 50 per cent of the difference in value between a 'good' car and a 'lemon'. The result of such (rational) behaviour is a severe distortion of the market. If the seller of a good car knows that his or her offering will sell for 50 per cent less than its true value, due to the presence of lemons elsewhere in the market, he or she will be less likely to sell it at all. Conversely, potential sellers of 'lemons' can be confident that their offerings will go for 50 per cent more than true value, and they

will have a greater incentive to sell 'lemons'. Eventually, only 'lemons' will be available on the used car market, and the market will collapse.

Pisano argued that in licensing deals among biotechnology companies, the prospective licensee does not know the true quality of the project on offer. He or she may have difficulty in finding out. While the licensee can conduct extensive due diligence, inevitably some critical information will not be passed across to buyers, either because the seller is unwilling to do so or because they are unable to. The seller clearly wants to present the project in as favourable a light as possible. Indeed, were the seller to hand over all information, the licensee would have little need to pay anything for the license, having already obtained the needed information.

Under such circumstances, licensees must discount how much they are willing to pay for licenses, and the 'lemons' dynamic potentially kicks in. To test whether it in fact did kick in, Pisano analysed data on 260 biotechnology projects. He asked whether licensed projects suffered a statistically significant lower success rate than non-licensed projects, all other factors being taken into account. He found that partnered projects were only 46 per cent as likely to succeed as non-partnered. This is a large difference. It implies that eliminating the 'lemons' effect could effectively double the success rate in partnered projects. The implication was clear: the market for knowledge is likely to be inhibited as more firms experience the 'lemons' problems with projects they in-license. Innovation risk is thus more difficult to manage through intellectual property markets.

The second major problem of asymmetric information, moral hazard, results from the creation of an incentive to undertake more risky behaviour, or even to cheat, once the risk of doing so has been sold to another party. The classic example given by economists is fire insurance. Once property owners are assured that the consequences to them of a catastrophic fire have been sufficiently reduced or eliminated through insurance, they may reduce their commitment to, and expenditure on, fire reduction equipment and practices. At the extreme, they may even deliberately create fires to reap the reward of having sold the risk to the insurer.

This problem is especially important for innovation. The gains from innovation come from activities and projects that are inherently risky. What constrains innovators from pushing forward with risk is the consequences of failure – loss of their investment and the time committed to the project. If any agency effectively 'insures' the innovator against all risk, whether it be an investor, a bank, or a government, while leaving the potential innovator in control of key decisions, the potential exists for the innovator to skew their projects towards only the most risky. With the downside taken care of by someone else, why not shoot for a big upside? While the 'insurer', particularly if it is a government, may in fact be attempting to encourage innovators to be more adventurous, completely removing risk may tempt the innovator towards excessive risk-taking.

The two problems outlined here are well recognised by economists and historians of markets. They are both information problems, in which incentives exist for parties on one or both sides of a transaction not to share information. The consequence of information asymmetry is to undermine the willingness and ability of market participants to buy and sell risk. Its presence means that markets for knowledge ('intellectual property') rarely function smoothly. Even good ideas are so heavily discounted that innovators frequently fail to gain sufficient returns to justify the resource commitment required to undertake them.

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is innovation risk managed

by markets alone. ...

Nations that have  
succeeded in establishing  
sets of institutions to  
achieve such risk-sharing  
have succeeded in  
innovating in the complex  
and uncertain fields of  
software, electronics and  
the life sciences. Those that  
haven't developed such

'national systems of  
innovation' have failed to  
build those industries.

The information-processing demands of innovation, however, induce another whole class of problem that retards the smooth functioning of markets for risk. These are problems, not of information asymmetry but of information *absence*. The vital distinction between situations in which the probabilities of various outcomes can be known in advance, and hence managed with confidence through pooling and diversification techniques such as those discussed above, and those in which probabilities cannot be known in advance, was first highlighted by University of Chicago economist Frank Knight. Knight proposed two conceptually distinct categories, risk and uncertainty, for understanding what is commonly lumped together as 'risk', and suggested important implications for his distinction:

*The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation a priori or from statistics of past experience), while in the case of uncertainty that is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in such a high degree unique.<sup>5</sup>*

Innovation is clearly in Knight's second category. This is a critical distinction for economic practice:

*The best example of uncertainty is in connection with the exercise of judgment or the formation of opinions as to the future course of events, which opinions (and not scientific knowledge) actually guide most of our conduct. Now if the distribution of the different possible outcomes in a group of instances is known, it is possible to get rid of any real uncertainty by the expedient of grouping or 'consolidating' instances.<sup>6</sup>*

Knight argued that if the probabilities could *not* be known in advance, the tools of 'consolidation' or the 'insurance principle' – through portfolio diversification such as that discussed above would prove much less reliable:

*The application of the insurance principle, converting a larger contingent loss into a smaller fixed charge, depends upon the measurement of probability on the basis of a fairly accurate grouping into classes.<sup>7</sup>*

For innovation, such 'measurement of probability' and 'grouping into classes' is rarely possible. Innovation projects are by nature learning and knowledge-creation efforts. As such, each is unique. It is all the more important, therefore, that risk managers be able to make precisely informed judgments *about each specific case*. Doing this across organisational boundaries is always more difficult than within the shared culture and cognitive frame of a common organisation, at least if that organisation is healthy. The conclusion is that market-mediated inter-organisational relations inevitably inhibit, sometimes severely, the intimate knowledge and close relations essential to both knowledge integration and project selection for risk management. Escalating complexity and uncertainty have only exacerbated the difficulties to which Knight drew our attention.

To summarise, the growth of markets for risk is retarded in the case of innovation by three factors: inability to arrive at an agreed price due to asymmetric information; adverse selection leading to excessive discounting; and difficulty conducting learning and integration across organisational boundaries. These problems have meant that markets for intellectual property are flawed and poorly

developed, and in no successful economy is innovation risk managed by markets alone. It has proven necessary for innovation risk to be shared by institutions broader than the modern corporation. Nations that have succeeded in establishing sets of institutions to achieve such risk-sharing, without inducing adverse selection or moral hazard, have succeeded in innovating in the complex and uncertain fields of software, electronics and the life sciences. Those that haven't developed such 'national systems of innovation' have failed to build those industries.

## 5. Risk Management Vehicles

If markets can't bear the burden of innovation risk alone, who can? In fact, no one best vehicle exists that is optimal for all technologies. Because the structure of risk varies, so too must the structure and organisational form of risk management. Some types of risk require large and diverse management vehicles, others small and tightly integrated organisations. To manage innovation risk successfully, it is necessary to match the source of finance with the type of risk to be incurred. Greater scale means that larger individual minimum commitments must be made to participate in the experimentation process, which implies a larger portfolio. Greater risk intensity, or lower individual successful probabilities, must be offset by higher potential pay-offs. Longer duration means positions must be maintained for longer before a return can be expected, and often require ongoing rather than limited-lifespan vehicles.

Put simply, the greater the scale of commitment necessary, the lower the individual probability of success (greater the risk intensity), and the longer the duration of experimentation processes, the wider must be the base over which the risk-management vehicle must diversify. Vehicles to manage *minimal* risk are relatively straightforward to construct, and many nations possess them. But it is important to recognise that the vehicles required to manage larger, more intense and more prolonged risk must be larger, more complex and of longer duration. Fewer nations have been unable to construct these.

This fact explains why some nations are outstanding at entrepreneurship but poor at technological innovation, or vice versa, strong in invention but poor at entrepreneurship. In fact, most entrepreneurs don't innovate. Their new businesses create a 'me-too' product or service, incurring little technical risk. They start small and remain small, although such businesses can provide a generous income to an individual entrepreneur. While small, 'me-too' firms are numerous, they often enjoy only a relatively short lifespan. They contribute little to the growth of a modern capitalist economy, and little to technological innovation. Such ventures can be, and are, funded from undiversified personal resources, or from family and friends. Even for firms that eventually grow larger, most initial finance comes from undiversified sources.

But these businesses, too, while they might at the outset be financed from personal savings, as they grow and take on more ambitious innovation projects, they demand both more finance and more-diverse finance. Most such firms take several years to define a particular field in which they possess distinctive competence. During this period, their customers implicitly agree to share their risk. Most such companies succeed by 'out-hustling' others with similar ideas, though a few develop rapidly based on distinctive ideas from the outset.<sup>8</sup> Such firms typically must live for five to eight years before, if successful, they develop any competence that would merit

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formal venture financing. They also are often financed at first with a combination of personal assets and aggregated friends and family assets.

As risks become larger, of longer duration, and of greater intensity, increasingly broad *organisational* coordination is necessary if risk is to be effectively diversified. The range of possible risk-management and integration vehicles can be arrayed along a spectrum, from the simple and small scale, through to the large and complex. If the demands of particular innovation tasks are not matched to appropriate institutional and organisational vehicles, innovation will appear unacceptably risky and not be attempted.

For initially larger and/or riskier undertakings, sources of capital that appear small in the bigger picture assume much greater importance. Such ventures usually require finance beyond the reach of most individuals, and very likely beyond the resources of those who initiated the idea that spawns the company. These ventures are much riskier, and frequently require longer time frames before ideas either come to fruition or are shown to fail. To cope with such demands, entrepreneurs must turn to investors who can mobilise greater resources, and diversify the risk further.

The three main vehicles for financing innovation investment in a modern economy are: large corporations, including banks; venture capital and other pools of private investors; and government. At an early stage, formal equity and debt markets – the stock and bond markets – usually play little role. In almost no country other than Australia does the stock market attempt to finance innovation, especially in its early phases. Such markets usually become involved only much later, serving to enable the successful entrepreneur to monetise his or her investment and capital gains, and withdraw funds from both through an initial public offering. These vehicles play the vital roles of diversifying risk and overcoming information asymmetry to select investments. But each enjoys a divergent set of strengths, and suffers different weaknesses.

Large corporations can usually gain superior information about the character of innovation projects. In theory at least, they have full access to the data and judgments generated by their employees on the risks and potential returns of innovation projects under consideration. They can also combine and integrate information, in an ongoing and cumulative social learning process, over time expanding their capability both to manage and to assess such projects. Their information flow is, of course, subject to the vicissitudes of organisational politics – empire-building, career-positioning, pleasing the boss and so on – but by keeping information internal to the organisation, calling upon the effort and commitment of employees, and holding employees accountable for their performance over time, large corporations do have a better chance to acquire the information needed to select the best projects for inclusion in their portfolio.

On the disadvantage side of the ledger, such a portfolio will necessarily be circumscribed in several ways. First, the number of projects included cannot grow very large. A company can conceivably manage tens, perhaps even hundreds of projects, but not thousands. Second, the aggregate resources that can be committed will be limited by the firm's size, its cash flow, and industry norms about the appropriate ratio of sales to R&D expenditure. Third, to achieve the advantages of knowledge integration, and to make project management effective, firms must not

diversify too far from their core expertise. Management must know enough and have sufficient experience to make informed judgments about the projects selected for their portfolio. Equity and bond markets are sceptical of firms that attempt to expand into arenas in which the firm lacks established competence and experience. Fourth, public firms, in particular, need to satisfy the short-term cash-flow interests of their investors. Given the favourable tax treatment that prevails for dividends, in Australia especially, investors in public firms expect that management will pay out a large proportion of earnings to shareholders, limiting what can be retained for investment in future innovation. They also expect that firms will not undertake activities that are disproportionately more risky than those in the operational core.

These four factors limit in practice how much true diversification a public firm can achieve for innovation projects: the projects must be related reasonably closely to the firm's core activities, they must not be too risky or too different, there must not be too many of them, and the quantity of resources retained for investment in innovation must not be too great. In short, while corporations can usually enjoy access to better information than markets, the breadth of diversification than can be achieved without jeopardising relations with markets is inherently limited. Corporations thus are most capable at managing medium-sized portfolios of related projects, none of which is too large or risky by comparison to the firm itself. Ideally, their projects would be closely related to, and they would leverage and strengthen the firm's core operational activities.

Venture capital is the second organisational form through which innovation risk is managed in free-market economies. Venture capital pools differ from companies, in that they seek to invest in entirely new, potentially high-growth, businesses, grow them, and sell their stakes when mature, rather than manage them over the long term. These young businesses can be quite unrelated to one another; indeed, from the perspective of achieving true diversification – unrelated risks – it is ideal that they are quite different. But venture capitalists differ from other pooled investment funds in that they seek to add their own expertise about growing small companies to those of existing management teams, improving the probability that their firms will succeed.

The lifespan of a venture fund is finite, usually seven years. Other investment groups, such as pension funds or wealthy individuals, commit a proportion, usually a small proportion, of their resources to the venture fund in the hope of gaining far above average returns, more than compensating for the extra risk they assume. Venture funds range in size from a few million dollars to about a billion. Venture capitalists hope to make investments in a limited number of companies, typically 10 to 30, of a few million dollars each. Their goal is to recognise opportunities that others do not, buy a stake early, help mature these businesses, and ultimately bring their products to market, before selling their stake for a large gain. This process is, of course, inherently high risk. By investing in businesses that have yet to prove themselves in actual markets, venture capitalists accept, and hope to master, a high degree of risk.

How do they do this? To what types of risk are venture capitalists best suited? In essence, venture capitalists aim to combine more diversification than companies can gain with better knowledge than equity markets of opportunities for business growth. Venture capitalists aspire to know more than markets – to see the opportunities faster, apply better skills to analyse opportunities, and employ

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Like all other risk-management vehicles, venture capitalists are expert in only certain types of businesses and certain types of risk. They specialise in understanding market and managerial issues. They are rarely qualified to assess or cope with technical risk.

superior management expertise to help their businesses grow – and to pool a sufficient range of investments that the inevitable failures are more than compensated for by the winners.

But, like all other risk-management vehicles, venture capitalists are expert in only certain types of businesses and certain types of risk. They specialise in understanding market and managerial issues. They are rarely qualified to assess or cope with technical risk. Unlike companies, therefore, most venture capitalists attempt to remove or substantially reduce technological risk before committing to an investment. Discussions between technological entrepreneurs and venture capitalists typically begin with at least 'proof of concept': demonstration that the device, software program, or service will actually function as claimed.

In the fields in which venture capital has flourished, in particular information technology, software and telecommunication devices, these conditions can be met. It is usually possible to show at the outset that the proposed concept of a young company is technically feasible and practical, at least in principle. A working prototype or mock-up can be assembled. The underlying physics and engineering are usually well characterised. This is true as well of electronics and the semiconductor industry.

In these fields, other parameters amenable to venture funds are also met. Projects typically take less than five years to bring to fruition or to fail. This is critical for venture funds, for in the seven-year lifespan of a typical fund, one or two years will be devoted to finding suitable investments, and one or two years will be expended at the end to exit positions (successful or otherwise). That leaves only three to five years in which their firms must be tested. And in the industries in which venture capital has thrived the individual investments are not too large. If a typical fund invests \$100 million, and wants 20 positions, each investment cannot average more than \$5 million. This profile nicely fits the typical software company. It can be financed for a few million, takes a few years to test, and its technology can be well described in advance of financing the new firm. Of course, venture funds can combine their investments with others, but it is difficult to fund projects that require hundreds of millions of dollars, or many years, in this way.

The limits of venture capital are not apparent in the other major field of contemporary technological innovation: life sciences. Here, conditions amenable to venture capital are much less commonly achieved. First, technical risk cannot be taken off the table. Most life science projects and new companies come into being precisely to determine whether the company's concept will prove technically feasible. The underlying science is not mature or well understood, and scientific outcomes must be established by physical experimentation. Thus, in life sciences, potential investors confront irreducible risk of all three kinds. Assessing the kind of technical risk frequently encountered in life sciences demands deep and sophisticated knowledge of the focused sub-field within which the project will operate. And even with such knowledge, as in the case of scientific peer review, it is often possible to gain only an imprecise estimate of a project's success potential. Detailed familiarity with the current state of relevant literature, as well as knowledge of activity under way at leading labs worldwide, is often required to assess such projects. Certainly, very few venture capitalists, even those with advanced scientific training in a field of biology, are likely to possess the exact expertise required to estimate success probabilities in this field.

Further limitations are imposed upon venture capitalists in biotechnology by the typical size of their funds, the number of positions they wish to hold, and therefore the maximum size of commitment they consider it prudent to make to any one nascent company. These parameters will be driven by the venture capitalist's assessment of the success probability or risk intensity of the projects in which they will invest. For example, a \$300 million fund, investing \$10 million in each of 30 projects, with a potential pay off of three times initial investment, would need at least 10 successful projects (or 33 per cent success rate) to return its investments with no profit. To gain an industry-expected return of 40 per cent, the fund would need at least 14 successful projects (a 47 per cent success rate). If the expected success rate drops to 5 per cent (the rate many analysts think typical of pharmaceutical projects entering clinical trials), the return on the few successful projects must rise to 200 times to return the fund's capital, and 280 times to gain a 40 per cent return. Even if achievable, this is a highly skewed distribution of risk and returns.

Clearly, these are severe conditions to impose on any investment portfolio. The implication is that the minimum effective scale of a fund – the breadth of diversity it requires to be confident of meeting its targets – will be driven by a combination of the risk intensity (success probability) typical of the technology in which it seeks to invest, the minimum size of investment required, and the expected return for winners. Lower probabilities dictate greater diversification and larger total fund size. But even when these conditions are met, some very profitable investments offering potential returns many times their original invested capital may not be wise, under conditions of exceptionally low (but not unheard of) expected success rates.

The final major vehicle available to finance innovation is government. Government brings to the innovation challenge several major advantages over other risk-management contenders, along with two central weaknesses. The most obvious advantage is that government can diversify its risk over the widest base of all: the entire citizenry. Not only can it achieve huge diversification, but it can also broaden its capital raising, incorporating means from raising taxes to issuing its own debt. It can also diversify the form in which it takes its returns to include non-financial forms, such as more and better employment, better health outcomes, improved security, or simply enhanced national prestige and the betterment of humanity. On top of these advantages, it can readily take a long-term perspective, both in the investments it makes and in the way it finances them. Government would seem, then, to be an ideal risk-bearer, especially for large, complex and long-term projects. And indeed, government has often financed such projects, ranging from the space program, to Airbus, the new commercial-aircraft manufacturer in Europe, to laying the foundation for a semiconductor industry in Japan, Taiwan and Singapore.

But government suffers from two important drawbacks as a risk-taker, both stemming from the character of its resource-allocation and decision-making processes. First, precisely because government possesses such a broad range of responsibilities and powers, and can bear and survive large-scale risk – indeed, if it is the government of a significant economy, it can survive almost any financial risk – it can suffer from inherent discipline problems. Government can potentially invest in almost any project, even those with virtually no chance of success, and

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survive the consequences. Worse still, government, and especially non-elected government officials, face no competition. Government is simply not subject to the same market-based discipline as other risk-managers, or indeed virtually *any* discipline other than the public's scrutiny and willingness to bear taxes. It is a perfect monopoly. One consequence of all this is that government is particularly vulnerable to allocating resources to projects characterised by not only great risk, but little or no social pay-off.<sup>9</sup> This is especially so when such projects help politicians win re-election, either because they are popular or supported by wealthy backers.

The result is that government resource allocation can be deeply flawed. Key individuals in government rarely bear any risk on their own account; they are playing with other people's money. While in a democracy at least they need to retain public support, because government can readily delay financing its investment until after the current decision-makers have departed, governments can

allocate resources in ways that are popular today, but make little long-term sense. Frequently, too, these decisions are made by personnel with poor training or experience in financial risk management. A capital allocation system in which successful projects are those backed by friends of government officials or politicians is perhaps the worst form of risk-management available. And the greater the arena of responsibility allocated to government, the greater the probability such disaster will emerge.

How might such drawbacks be surmounted, to gain the advantages of government as a risk-bearer, but avoid the distorting effects of government decision-making processes? The answer is in the first place to circumscribe government's role to areas in which the market, or market-oriented vehicles, have been demonstrated not to work (that is, in which markets and other institutions fail, and not because they are simply bad ideas), and then to require both transparency and the strongest possible competition in resource allocation. Ideally, after broad public debate government would decide which areas of risk it *should bear* in the interests of social welfare, and then hand over decision-making on individual projects to a group or groups that are exposed to both public scrutiny and competition. The first condition requires that it be firmly established that the type of risk under consideration should be borne by someone – that is, that the potential project offers substantial social pay-off if successful – and that no other vehicle can do so, whether because the risk cannot be diversified, is too long term, or just too complex. The second

condition requires that government officials themselves *not* make risk-management investment and resource-allocation decisions, but that purpose-designed vehicles be developed for these tasks. One key is for government not to bear all risk, but only to share it with market exposed vehicles.

### **An Example: The Pharmaceutical Industry**

The fact that the structures of risk and appropriate management vehicles vary suggests that in large and complex sectors, such as health or defence, a division of labour will arise among various institutions for bearing risk. The pharmaceutical industry of the United States, the world leader in this sector, provides an instructive example of how one such system divides responsibility.

Bringing a new drug to market requires successful navigation of a multi-stage, time-consuming and labyrinthine process. In 2004, the cost of developing and

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testing a new drug was estimated to be greater than \$1 billion, and to take more than 10 years. These two features alone suggest the need for both large and patient sources of capital. But in addition, drug development is highly risky, and returns come from only a very few successful projects. Ninety-five per cent of drug candidates entering clinical trials fail to gain final approval and don't get to market. And immediately successful drugs come off patent, imitators produce generic copies and prices plummet. Yet, year after year the pharmaceutical industry is on average among the most profitable in the world. This fact implies that the 5 per cent of new drug candidates that *do* make it to market can deliver very large sales and high margins. In other words, while new products produce sufficiently strong profits to make the industry one of the fastest growing and highest margin in the world, for the industry taken as a whole, risk is lumpy, long-term, and returns are highly skewed.

Significantly for the present discussion, the industry cannot be considered as a single entity. Each of the risk parameters discussed above varies as a drug candidate moves through the stages of the R&D process. The likelihood of a product succeeding rises as it crosses key hurdles, as is illustrated in Table 2.1.

**Table 2.1: Launch probability and project numbers in the pharmaceutical industry**

Number of projects for probability of one launch						
33 333	10 000	100	20	5	2	
Probability of market introduction from stage:						
0.003%	0.01%	1%	5%	20%	50%	
Target generation	Lead generation	Preclinical trials	Phase I clinicals	Phase II clinicals	Phase III clinicals	Market launch

(Source: Author's estimates)

During the earliest stages, in which scientists search for target molecules in the biochemical chains that cause disease (a process known in the industry as 'target generation') and then look for active molecules that can disrupt those disease-inducing chains ('lead generation'), the probability of any individual project producing a successful drug is exceedingly low, in fact on the order of 1 in 33 000 (for target generation) or 1 in 10 000 (for lead generation). As candidates move into preclinical (animal trials) stage, the odds of success rise to 1 in 100; then in clinical trials (testing in humans) the odds rise from 1 in 20 for Phase I (which tests in a small sample whether the drug is safe), to 1 in 5 for Phase II (which tests efficacy, also in a small sample), to 1 in 2 for Phase III trials (a large, statistically significant sample). The process from preclinical to Phase III clinicals typically takes about 10 years.

By combining this information on probabilities with the cost of undertaking such projects, it is possible to estimate the degree of diversification required to manage risk adequately. The cost of bringing a single product through Phase II clinical trials is estimated to be US\$50 million; and through the end of Phase III, US\$500–800 million. Prior to clinical trials, projects are much smaller and cheaper, but many more are required. To ensure a likelihood of one project getting to market from the lead and target generation stage, tens of thousands of projects

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must be initiated, at a cost of billions of dollars. To be likely to succeed in taking a single potential new drug from Phase I through to the end of Phase II clinical trials, an organisation needs to start about 20 (carefully selected) projects, which if they did cost our estimated average \$50 million each (some drop out before Phase II, of course, providing some savings), it would suggest a portfolio of around \$1 billion. To take the drugs through to the end of Phase III calls for an additional commitment of around \$1 billion, bringing the total portfolio to around \$2 billion.

What sort of organisations can manage a risk of such magnitude? Clearly, a division of labour is required. How the US innovation system divides the tasks is outlined in Table 2.2.

**Table 2.2: Risk management division of labour in the pharmaceutical industry**

Risk manager		Risk manager		Risk manager		
Government and Not-for-profits		Venture capital and pharmaceutical companies.		Pharmaceutical companies.		
Portfolio 10 000s projects.		Portfolio 10s-100s projects		Portfolio < 10 projects		
\$10s billions.		\$100s millions.		\$2-4 billions.		
Project selection on basis of science.		Project selection on commercial and science basis.		Project selection on commercial basis.		
Number of projects for probability of one launch						
33 333	10 000	100	20	5	2	
Probability of market introduction from stage:						
0.003%	0.01%	1%	5%	20%	50%	
Target generation	Lead generation	Preclinical trials	Phase I clinicals	Phase II clinicals	Phase III clinicals	Market launch

(Source: Author's estimates)

No single organisation could possibly operate and coordinate tens of thousands of projects, at a cost in the billions of dollars, other than the government, which in the United States combines with an extensive network of not-for-profit organisations such as the leading research universities to shoulder the task. The US government overcomes the drawbacks of the government resource-allocation process referred to above, not by refusing to 'pick winners' (in Australian parlance) or absenting itself, in the hope the market will pick up the ball, but by selecting a sector, in this instance biology, then 'outsourcing' resource-allocation decisions to a decentralised network of scientific peer-review panels. These panels attempt to ensure that the money flows to the most scientifically promising projects, and that results and prospects are reviewed by those closest to the field. The system is, of course, far from perfect – it is subject to personality politics, entrenched interests, distortions due to professional jealousy, and many other pressures – but by and large it works. The result is that the United States has a commanding lead in basic science, and a proliferation of prospects for new drugs. Note that at this stage the US system *does not* attempt to rely on equity markets to finance research and development.

At the next stage, in which tens of projects are needed to gain sufficient diversification, matters are less clear. Venture capital is certainly active in financing early clinical trials for promising candidates in the United States, as are

pharmaceutical companies. But even in an economy the size of the United States, few venture capital organisations can build a \$1 billion portfolio of drug development projects. This stage of the development chain is therefore still problematic, and it is the arena in which many of the difficulties cited in the previous section surface most noticeably. Without strong ties to pharmaceutical companies, it is unlikely this phase of the development process could adequately be funded, even in the United States.

For stage III clinical trials and beyond, to marketing and distribution, only the pharmaceutical companies can both make the required judgments and finance a sufficiently large portfolio. The rising cost of the complex and expensive clinical trials now required to meet regulatory approval, and hence the even greater size of project portfolio required to diversify the risk, is certainly one factor behind the merger wave experienced by the global pharmaceutical industry in the late 1990s.

The calculations cited above apply to any typical pharmaceutical product, whether biotech-derived or traditional small-molecule chemistry. But the pharmaceutical industry is only one example of such a division of labour. The important insight here is that no one-best, one-size fits all, mechanism exists for innovation risk management in a modern economy. What works best for the barber shop or family construction company will be unlikely to serve the needs of a new commercial aircraft manufacturer. As the balance between risk and reward tilts and narrows, and the degree of technical expertise required expands, the base over which risk must be diversified widens. It shifts from individuals, to families, to small-pooled vehicles such as angel funds, to medium-sized pooled funds such as venture-capitalists, and then to very large pooled funds such as pension funds, and ultimately to government itself.

The kinds of institutional structures a society develops for managing risk plays a determinative role in shaping in which technologies the society specialise, and what types of businesses are formed. To undertake entrepreneurship in highly complex and uncertain technologies, requiring the coordination of many specialists and experiments over long periods of time, requires the pre-existence of large and diverse institutions capable of managing the scale and scope of the risk created therein.

## 7. Australia's Innovation System

A key role then, and perhaps the key role of an innovation system, is to meet these needs. Institutional arrangements that satisfy these demands facilitate innovation; those that do not retard it. An important distinction among national innovation systems is the relative emphasis they place on one or other of the vehicles discussed above for entrepreneurial finance and risk management. Which vehicles predominate can exercise a strong influence over the types of risk the nation's system is best equipped to manage, and, in turn, to which type of technology it will be most comfortable committing. The nature of the dynamic 'fit' between the technically derived structure of risk, as described above, and various forms of risk management vehicle, is complex. While all approaches are employed to at least some extent in most successful countries, the weight given to each varies considerably. US and 'Anglo-Saxon capitalism' typically relies more heavily on venture capital; European 'welfare capitalism' gives a greater role to government and banks; and Japanese '*keiretsu* capitalism' relies more on large corporations<sup>10</sup>.

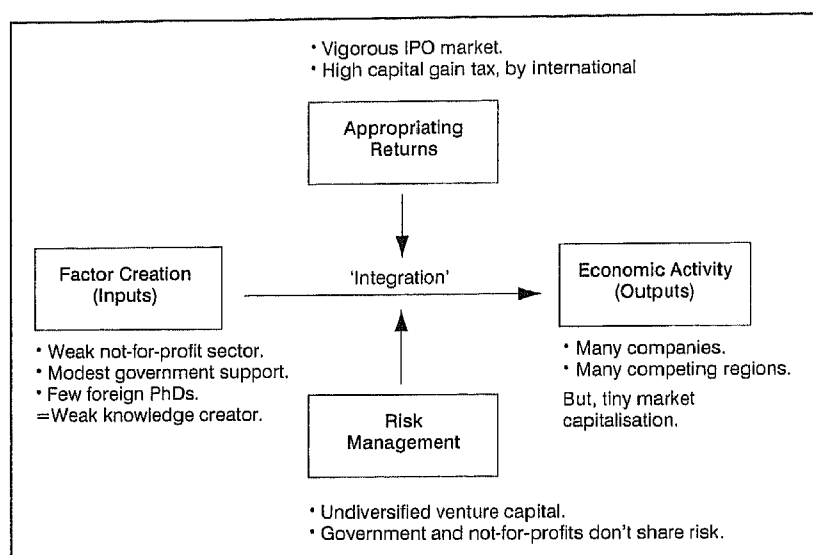
The US government overcomes the drawbacks of the government resource-allocation process, not by refusing to 'pick winners' (in Australian parlance) or absenting itself, in the hope the market will pick up the ball, but by selecting a sector, such as biology, then 'outsourcing' resource-allocation decisions to a decentralised network of scientific peer-review panels.



How does Australia's innovation system measure up as a risk manager? Unfortunately, Australia's innovation system fails on the two fronts most often cited by critics; that is, its low level of support for factor creation, in particular in education and basic research, and its poor allowance for capturing above-normal profits from innovation (through, for example, capital gains tax concessions and premium prices).

How does Australia's innovation system measure up as a risk manager? Unfortunately, Australia's innovation system fails on the two fronts most often cited by critics; that is, its low level of support for factor creation, in particular in education and basic research, and its poor allowance for capturing above-normal profits from innovation (through, for example, capital gains tax concessions and premium prices). It also fails on the creation of an effective risk-management vehicle, suited for the tasks of contemporary innovation. The Australian innovation system is summarised schematically in Figure 2.1.

**Figure 2.1: Australia's innovation system**



On the factor-creation side of education, training and basic research (the creation of 'options' to be tested in development activities), Australia's system is weak. The not-for-profit sector is small, and does not orient towards innovation. It is not encouraged by government with favourable tax treatment or other means. Australia lacks a tradition of broad-based giving to science and education, such as exists in the United States, and it does little to encourage its development. Australia rather pursues never-ending debates as to whether a certain activity should be public sector (government) or private sector (business). Other than sporadic lamentation of the lack of a philanthropic 'culture', few participants in the debate seriously consider how to develop a sector independent from either, to form the basis of factor creation in innovation.

For returns appropriation, Australia's system is also not encouraging. Capital gains are taxed at a much higher rate in Australia than in competitor countries (the United States taxes capital gains at 15 per cent, for example, compared to Australia's 25 per cent), and no encouragement is given to innovators within that regime. Prices for innovative goods such as new drugs are pushed downwards by government in Australia, and little preference is shown for local innovators in government purchasing.

But the situation is worse for risk management. Despite recent growth, Australia has developed little venture capital, and most of what does exist avoids technologically risky investments. Only 5 per cent of the already small venture capital pool in Australia goes to biotechnology, for example, a sector several Australian governments have identified as one the nation would like to develop.<sup>11</sup> Australia's large companies have among the lowest ratios of R&D expenditure to sales in the world, reflecting the fact they are largely confined to non-innovation-oriented sectors in which such investment is peripheral to competitive success. Government does not share innovation risk, beyond a scattering of programs at the initial start-up phase (an approach that exacerbates the problem of excessive fragmentation). In short, none of the vehicles most successful in innovating nations that are employed to manage innovation risk are well developed in Australia.

## 8. Conclusion

These characteristics of the Australian innovation system all derive from a common underlying philosophy. Today's policymaking elite is convinced that:

- innovation should be driven by the market
- it is inappropriate for the institutional system to discriminate between innovation and replication as economic activities
- the system should not discriminate among types of technologies (these beliefs are often summarised in the Australian phrase, 'the playing field must be level')
- if the market does not support innovation, so be it.

This philosophy, and the set of institutional and policy approaches it has shaped, makes perfect sense if Australia wants only to consume technology, and not to produce it. If, on the other hand, Australia aspires to be a participant in technology creation – and there are powerful arguments that it ultimately must be if it is to remain prosperous and technologically capable – then it needs now to investigate how appropriate risk management vehicles can be developed. It should be apparent that the market alone will not come to the nation's rescue.

Despite recent growth, Australia has developed little venture capital, and most of what does exist avoids technologically risky investments. Only 5 per cent of the already small venture capital pool in Australia goes to biotechnology, for example, a sector several Australian governments have identified as one the nation would like to develop.



## Endnotes

- 1 Ludwig von Mises, *Human Action: A Treatise on Economics*, fourth revised edition, Fox & Wilkes: San Francisco, 1996.
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- 3 Gary Pisano, 'R&D Performance, Collaborative Arrangements, and the Market-for-Know-How: A Test of the "Lemons" Hypothesis in Biotechnology,' *Harvard Business School Working Paper*, pp. 97-105, 1997.
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